Thermal Response of a Two-Phase Near-Critical Fluid in Low Gravity: Strong Gas Overheating as Due to a Particular Phase Distribution

R. Wunenburger, Y. Garrabos, and C. Lecoutre-Chabot
Institut de Chimie de la Matière Condensée de Bordeaux
CNRS
Avenue Dr. A. Schweitzer
F-33608 Pessac Cedex, France

D. Beysens
Service des Basses Températures
ESEME/SBT/CEA
17 rue des Martyrs
F-38054 Grenoble, France

J. Hegseth
Department of Physics
University of New Orleans
New Orleans, LA 70148 U.S.A.

We first report on an experimental study of the thermal response to a temperature quench of two-phase near-critical SF_6 in low gravity for an initial temperature ranging from 0.1K to 10.1K from the critical temperature. Temperature was measured simultaneously in gas, liquid and cell wall by thermistors and the density distribution was observed by interferometry. During the quench the gas temperature exceeded considerably the temperature of the heating wall (overheating up to 23% of the wall temperature rise). The thermal equilibration was found to take place on the diffusive time scale. This thermal behavior is noticeably different from the thermal response numerically calculated under Earth's gravity without convection effects. This difference can be qualitatively explained by considering the gas or liquid nature of the thermal boundary layers developing at the heating cell wall, which are the motor of the adiabatic heat transfer (Piston Effect) occurring in fluids enclosed in a container of constant volume. In low gravity the gas phase shows up as a bubble that is isolated from the cell wall by the wetting liquid phase. The hot boundary layers compressing the fluid therefore develop in liquid only, allowing the gas to be overheated. Overheating is due to the compressibility factor which is larger in gas than in liquid. On the contrary, under Earth's gravity, the gas is in thermal contact with the cell walls, a situation that allows the overheating to be cancelled by a cold piston effect. The influence of heat and mass transfer between gas and liquid occurring at short time scales on the thermal behavior is also analyzed.

We present secondly a rough model of the above overheating phenomenon. We analyze the influence of the thermophysical properties of gas and liquid on the characteristic time scale t_{PE} of adiabatic heat transfer in low gravity. We do not consider the heat and mass transfer between gas and liquid. The time t_{PE} is found to be larger than that in one-phase fluid. We discuss the influence of the distance to the critical point as well as of the gas volume fraction on t_{PE}.